This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # R834386

Aquifer Risk Assessment Framework (ARAF)

STAR GRANT #R834386

Overview presented
By
Kip Solomon and Brian McPherson
March 23, 2010
Pittsburgh, PA

Acknowledgements

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- U.S. Department of Energy, National Energy Technology Laboratory, and Southwest Regional Partnership for Collaborative Research Efforts and Field Sites

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Outline

- What is the ARAF?

- New Characterization and Monitoring Tools

- New PDF Development Tools

- Case Study Applications: Field Injection Sites

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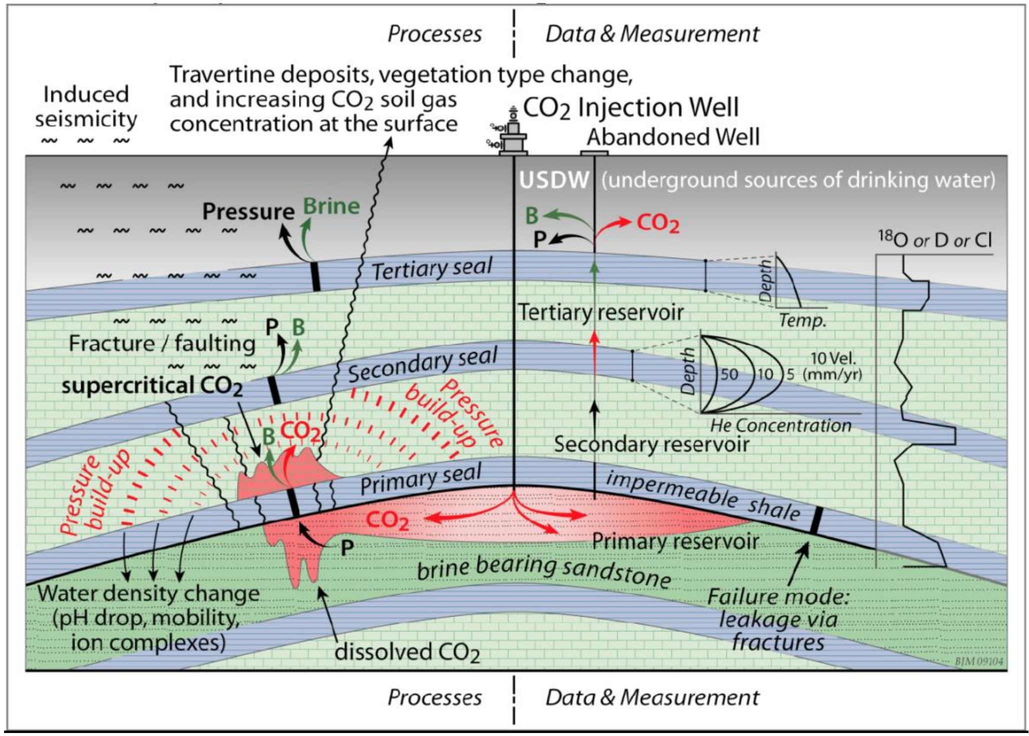
What is the ARAF?

The Aquifer Risk Assessment Framework, or ARAF, is a set of CCS risk assessment methodologies, integrated for systematic quantification of risks specific to USDWs.



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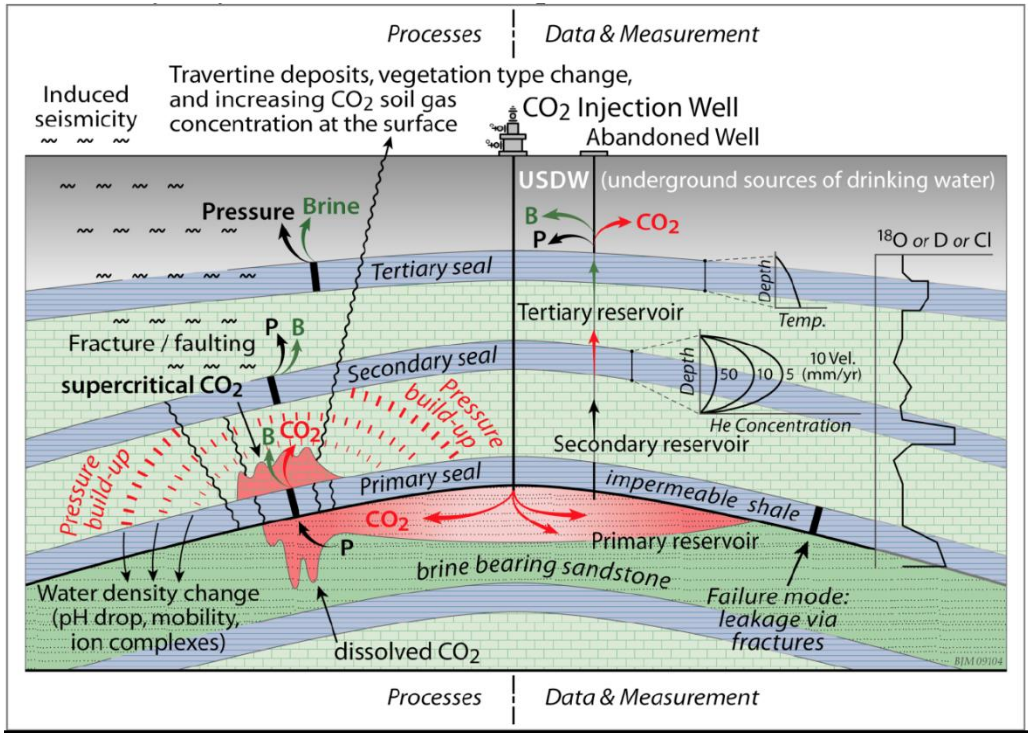

<u>These methodologies include:</u>

- new characterization and monitoring tools
- new risk Probability Density Function development tools
- a “blueprint” for systematic ARAF application, illustrated by case study examples

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What is CCS risk?

- Risk is defined as the product of the cost of a consequence and the probability of its occurrence:

$$R_{total} = \sum_{i} L_i \, p(i)$$

- The main issues for CCS and USDWs include:
  - public safety and health,
  - environmental (ecosystem) safety,
  - damage to other related natural resources (e.g., irrigation systems, etc.), and
  - financial loss for investors or insurers.

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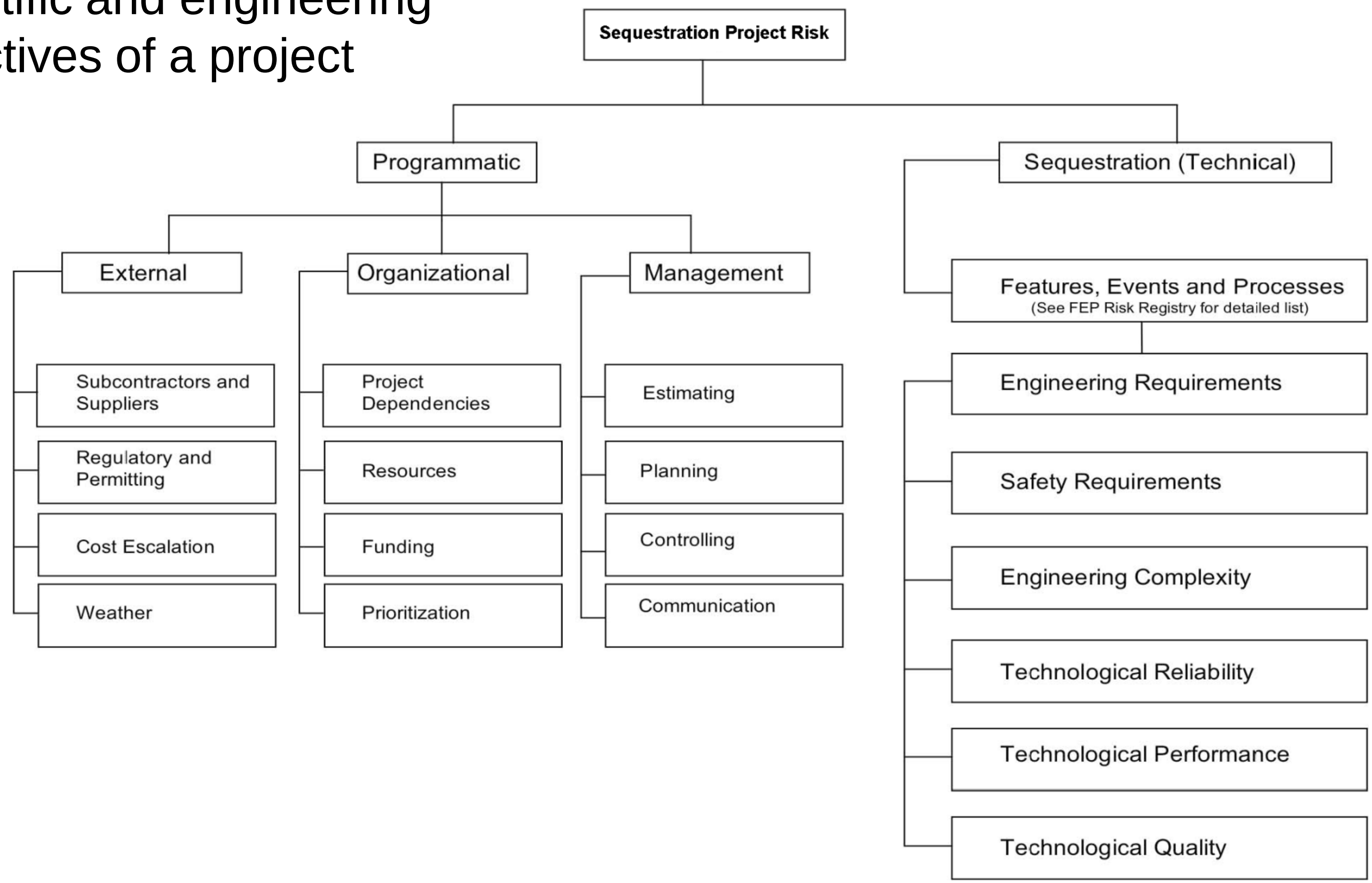
What risks are important in the ARAF?

- Programmatic risks that impede project progress or cost
- Technical risks inherent to the scientific and engineering objectives of a project



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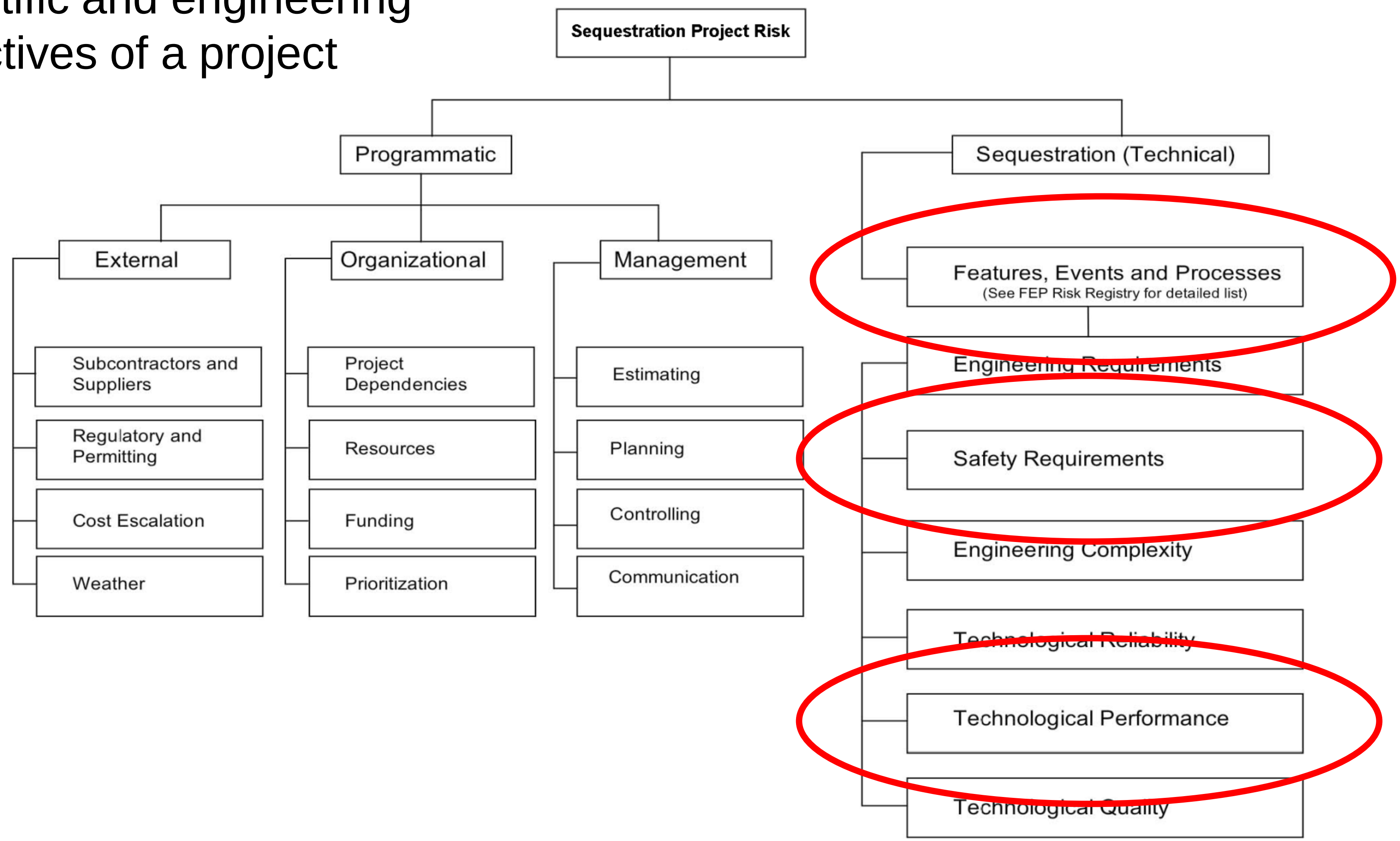

Where will the ARAF begin?

- FEPs, or Features, events, and processes
  - leaky wellbores or faults for features,
  - injection pressure increases or earthquakes for events, and
  - gravity-driven CO_2 movement or residual saturation trapping for processes.
- From FEPs, consequences are identified.

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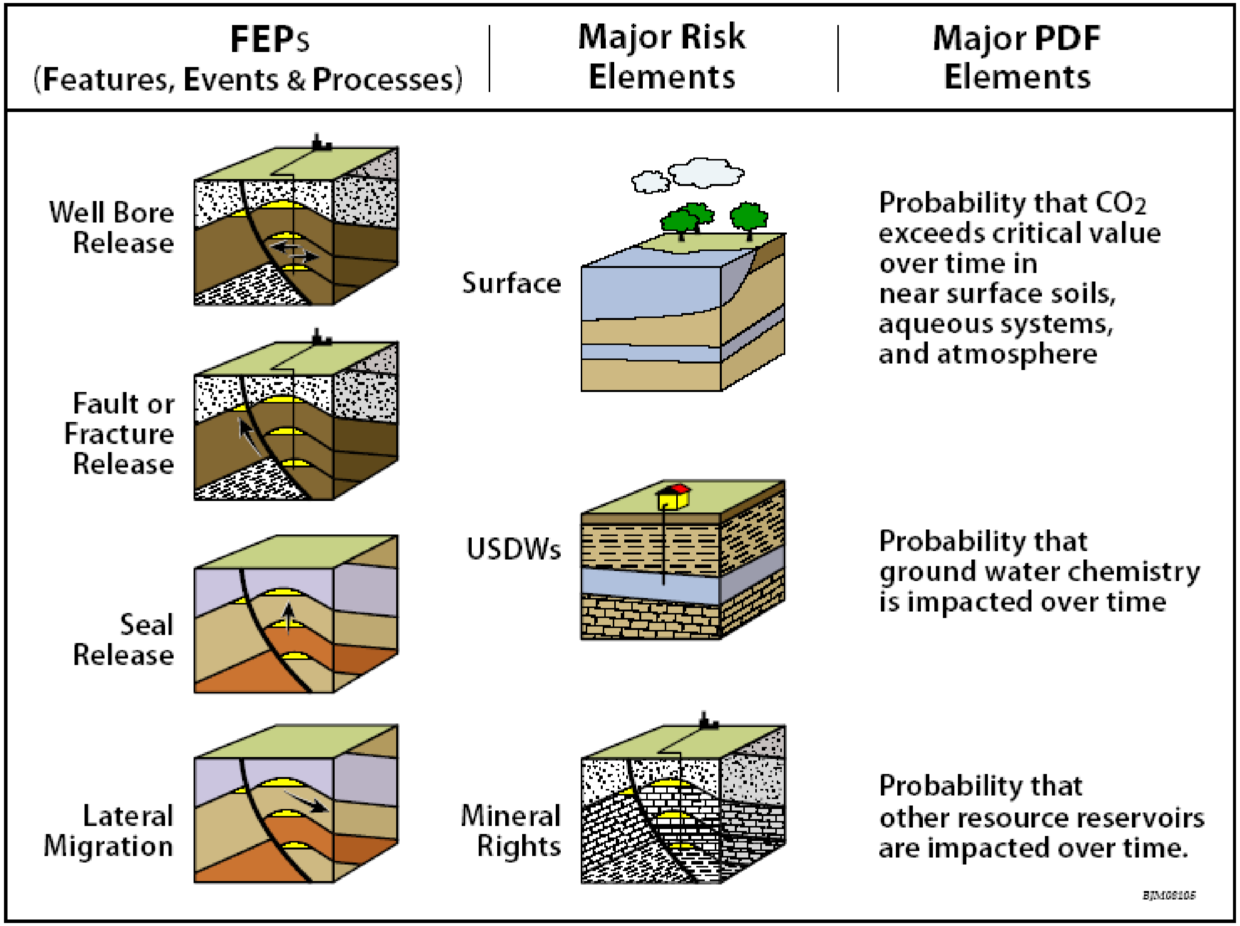
Where will the ARAF begin?

From

FEPs

to

PDFs



Concept of this graphic drawn from previous graphics by George Guthrie, NETL

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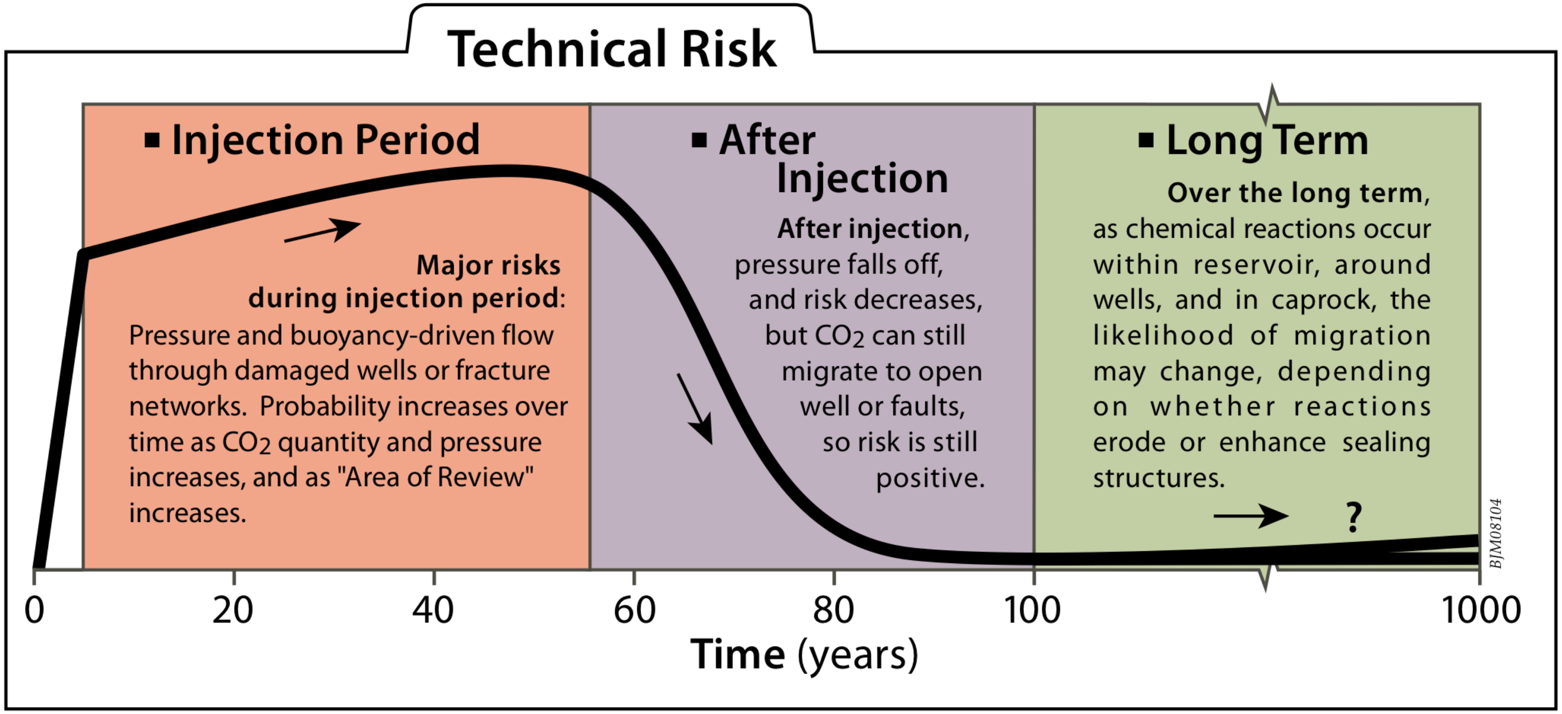
Where will the ARAF end?

The ARAF will track USDW risks for life of CCS



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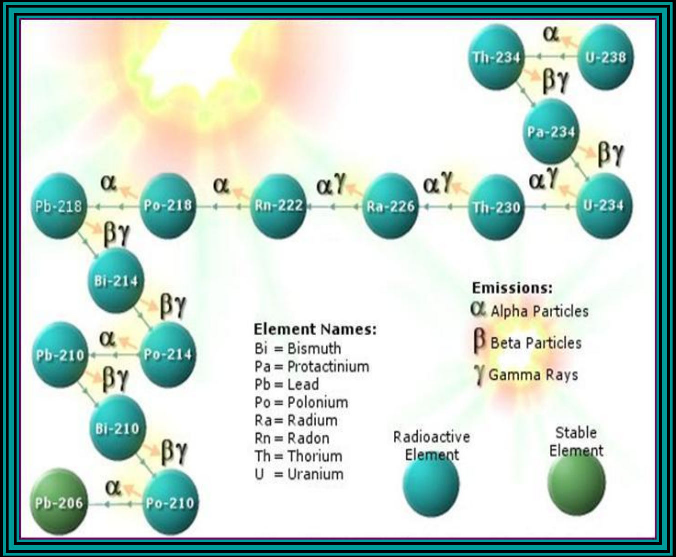
Internal Production ^{4}He

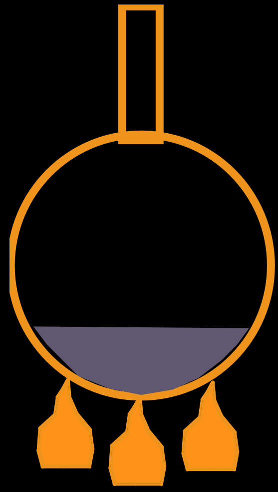
$^{238}U \rightarrow {}^{206}Pb + 8\ {}^{4}He$

$^{235}U \rightarrow {}^{207}Pb + 7\ {}^{4}He$

$^{232}Th \rightarrow {}^{208}Pb + 6\ {}^{4}He$

$= 0.5\ \mu cc\ m^{-3}\ yr^{-1}$





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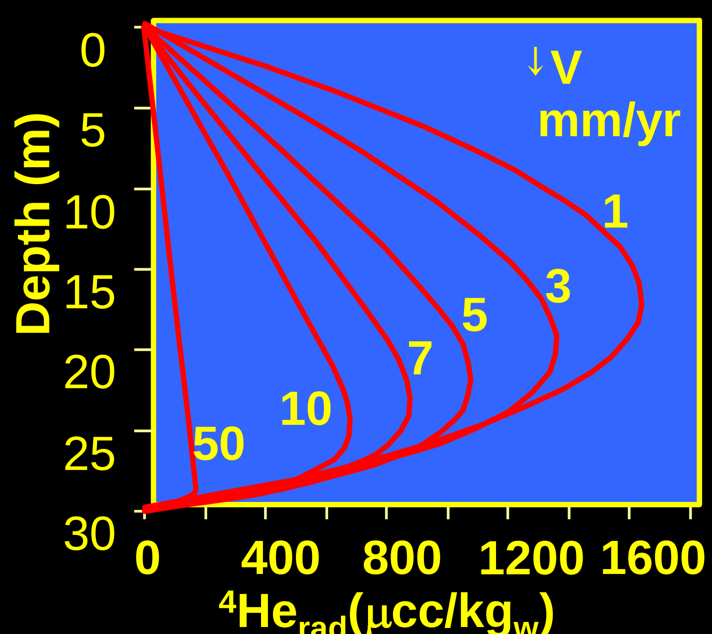
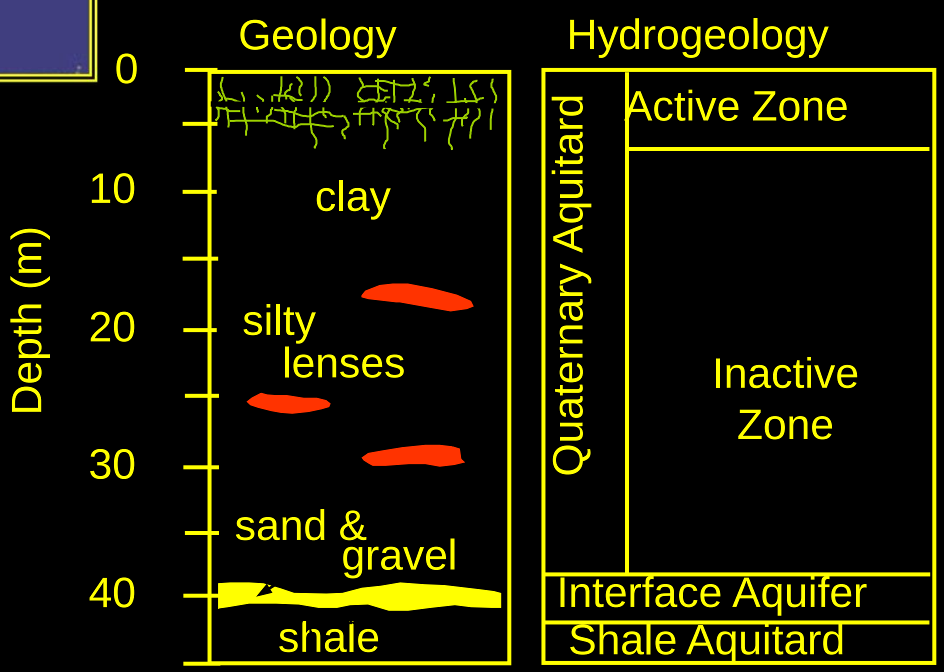
Till Sites in Ontario, Canada





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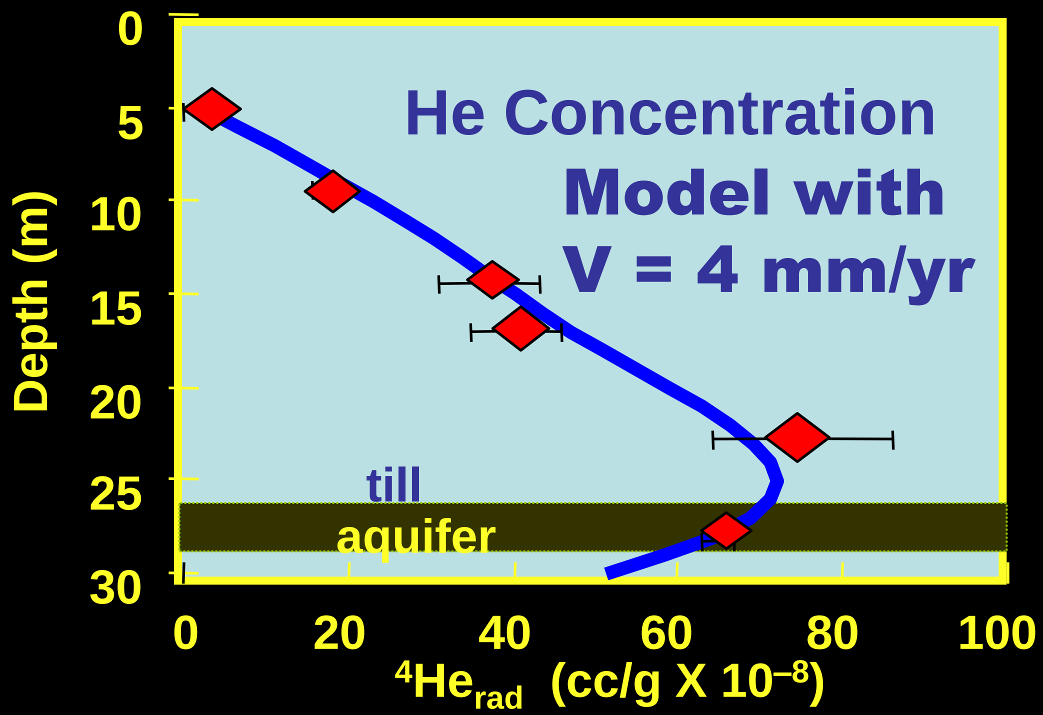
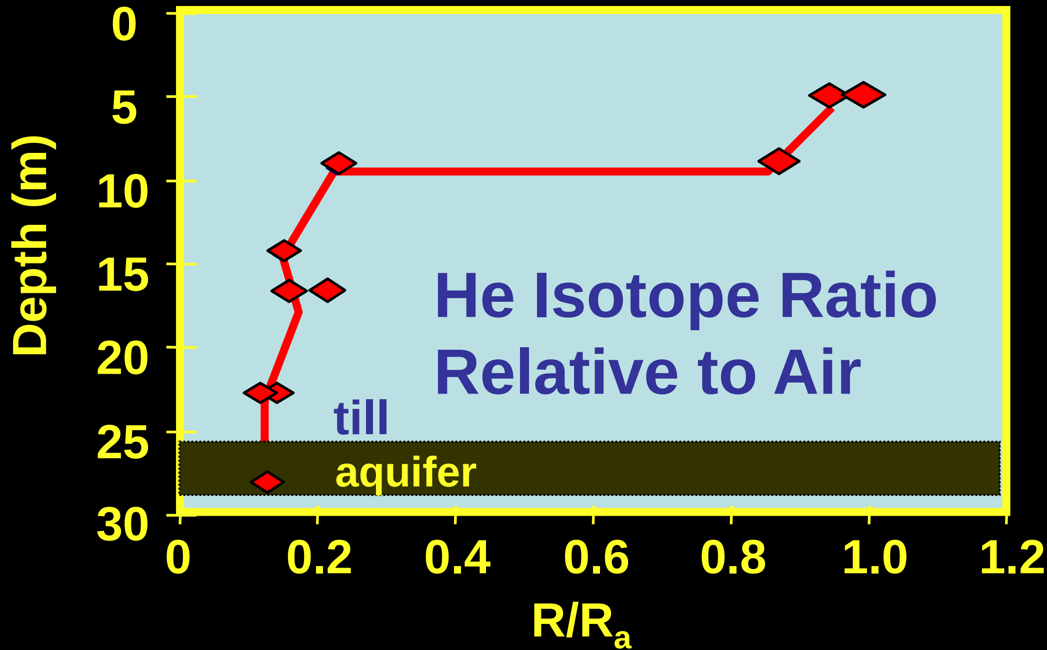
Warwick Site Ontario Canada





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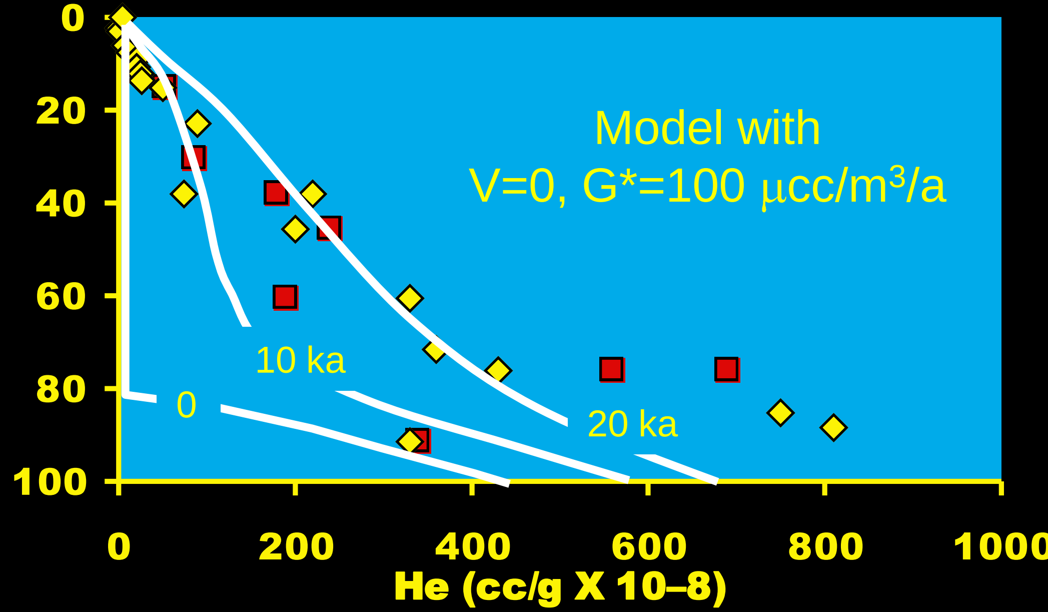
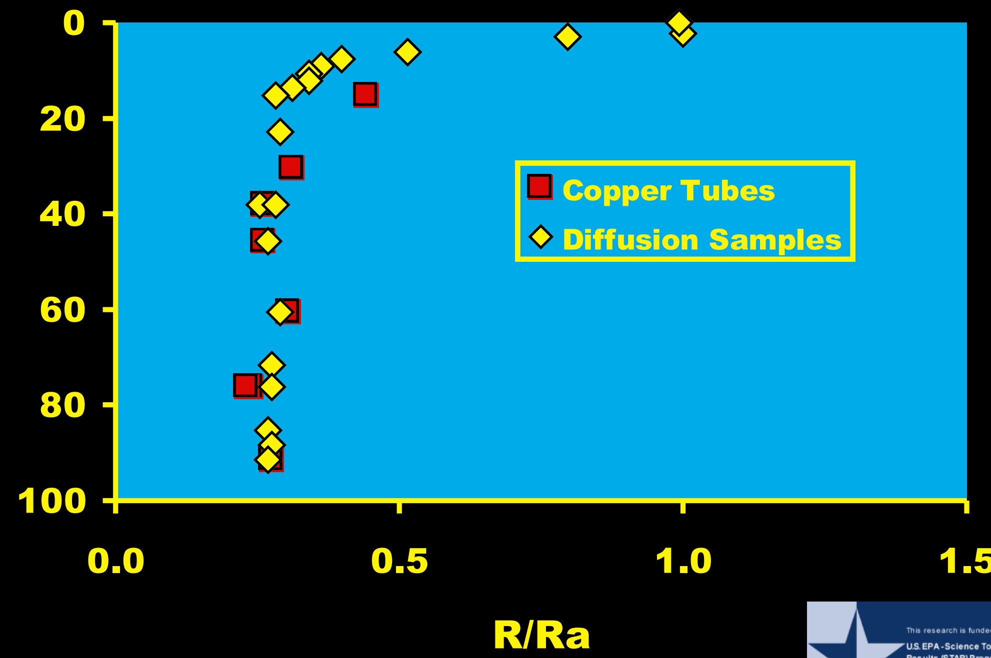
King Site Saskatchewan Canada





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Adapting to Deep Geologic Seals

- Gas concentration of pore waters is needed
  - Preferably at multiple depth
  - Very difficult to obtain from tight rocks at great depths
- We propose using the Helium content of quartz as a surrogate for pore water concentrations
  - Will permit this analysis on cuttings or core material (new or archived.)

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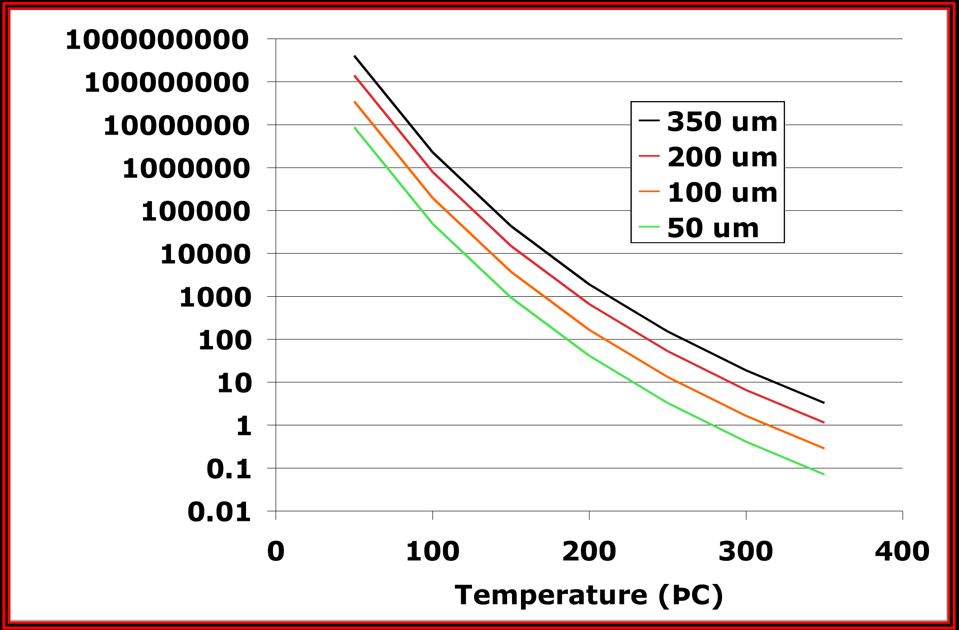
Approach



- Measure He conc. in qrtz
- Measure He “partition coef.” in same qrtz.
- Calculate in situ pore water concentration.
- Evaluate long-term transport; high He = low transport etc.

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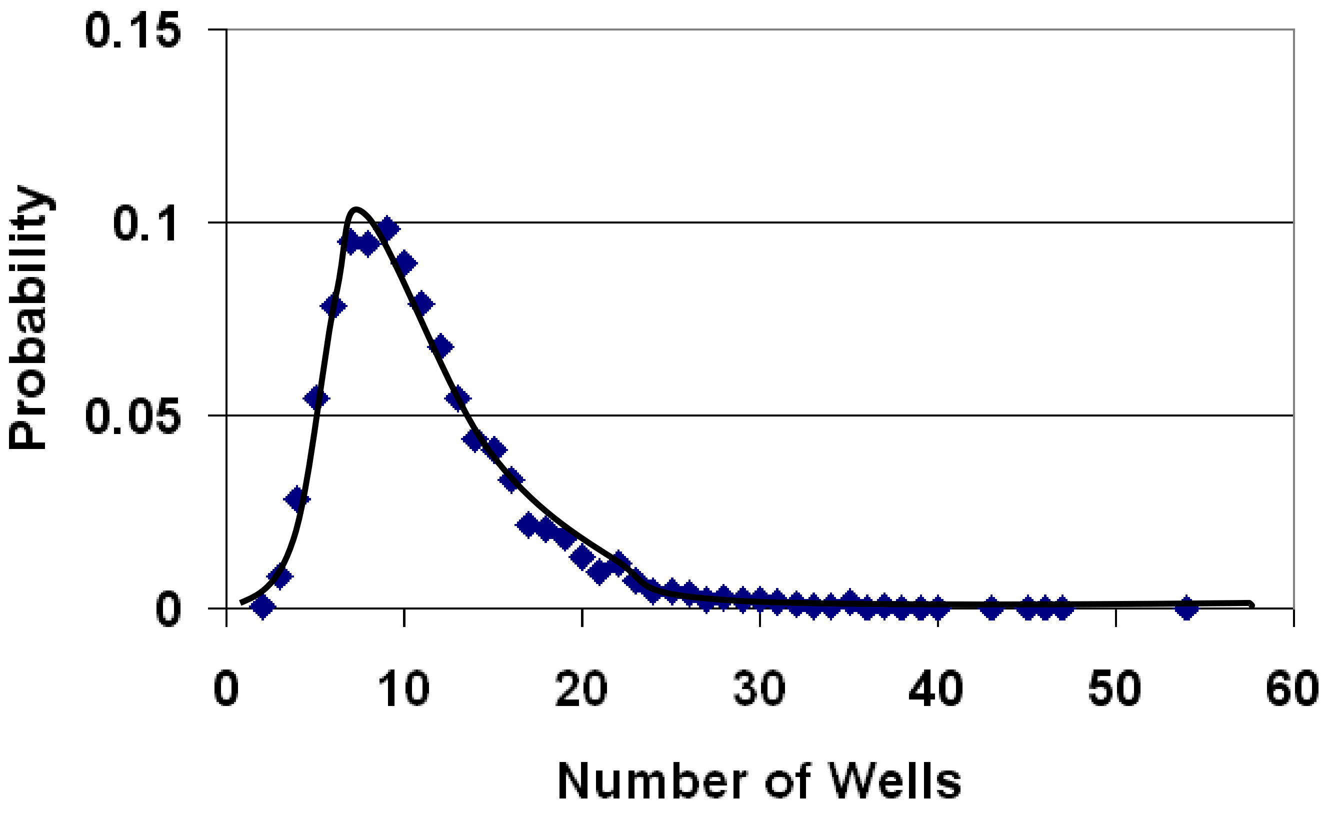
PDF Development Tools

Example PDF: Probability of Detected* Well Leakage as *f* (number of wells)



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PDF Development Tools

Development of PDFs requires:

$$R_{total} = \sum_i L_i \, p(i)$$

• detailed FEPs

• many, many simulations to characterize probability of risk

• additional analysis to characterize costs or impacts

• we are developing a PDF estimation tool by creating a "batch" interface reservoir simulator; at this time we are evaluating several existing software packages capable of facilitating such batch sets of simulations, including GoldSim, CO2-PENS, POWERSIM, and STELLA

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PDF Development Tools

But PDF development must be integrated with monitoring as well.

monitoring surveys continuous, with initial frequency established by site selection process…

…as **more monitoring** and characterization data gathered, *model resolution increases*

…as **model resolution increases**, simulation results used to guide *improvement of monitoring design*

…as **model results and monitoring design become more effective,** uncertainty associated with probability of FEPs will decrease, *PDFs better defined, and risk profiles (values) better resolved*

…as **risk profiles become better defined**, injection design and engineering can be modified to *improve and optimize - risk reduced*

…as **risk profiles better defined and risks reduced**, monitoring strategy can be tailored to reflect more focus on areas of greater relative risk *(devote fewer resources to areas of lower risk)*

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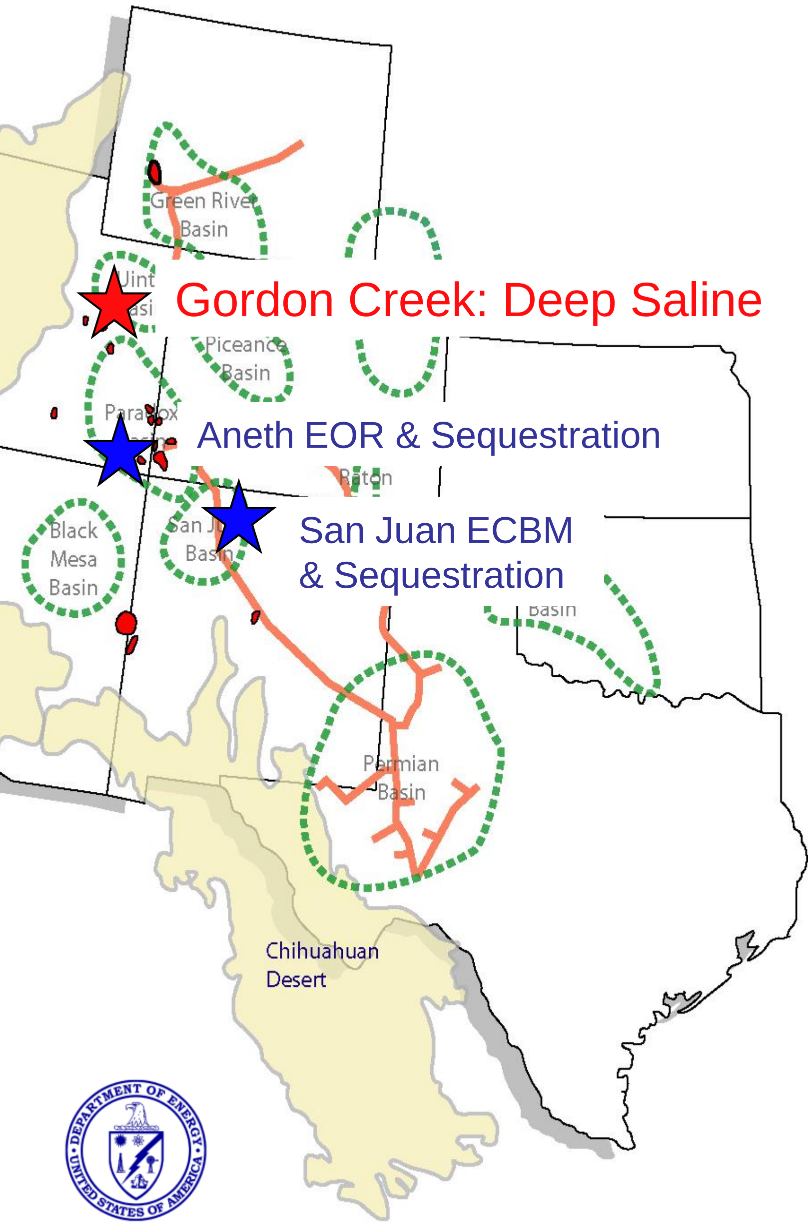
Southwest Regional Partnership on Carbon Sequestration



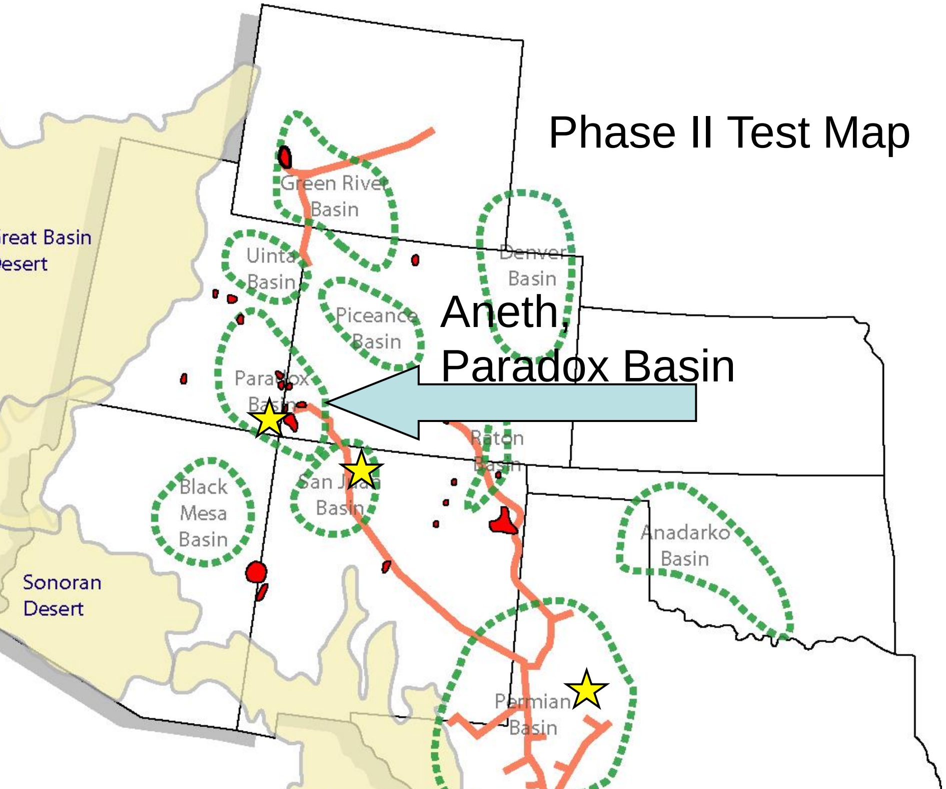
Aneth EOR & Sequestration:

- Injection began August 2007 and is ongoing
- 292,300 tons total injected in SWP wells
- Successful seismic imaging
- Successful tracer monitoring
- Successful concomitant EOR with net CO_2 storage

San Juan ECBM & Sequestration

- Injection began July 2008 and ended July 2009
- 18,400 tons injected in SWP injection well
- Successful vertical seismic profiling, tiltmeter deployment, tracer testing
- Successful enhanced methane recovery with net CO_2 sequestration

Aneth Field Site: Active Injection



San Juan Field Site: Post-Injection

Injection began July 30, 2008 (and ended 1 year later)

Gordon Creek Field Site:
Pre-Injection

Project Site Description: Gordon Creek, Utah

Period	Symb†	Formation / Member		Thickness (feet)	Depth (feet)*	Lith.
CRET	Km	Mancos Shale	Emery Ss Mbr		0	
			Blue Gate Sh Mbr	<250	3115	
			Ferron Ss Mbr	10-110	3250	
			Tununk Sh Mbr	200-300	4000	
	Kd	Dakota Sandstone		0-30	4025	
	Kcm	Cedar Mtn Fm	Upper member	150-750	4120	
			Buckhorn Cg Mbr	0-50		
JURASSIC	Jm	Morrison Formation		800±	4460	
	Js	Summerville Formation		120-180	5895	
	Jct	Curtis Formation		140-180	6275	
	Je	Entrada Formation		150-950	6585	
	Jc	Carmel Formation		300-700	7650	
	Jc	Page Sandstone		<70		
	Jgc	Navajo Sandstone		150-300	8400	
		Kayenta Formation		120-200	8750	
		Wingate Sandstone		300-400	8885	
TRIASSIC	Trc	Chinle Fm	Upper member	200-300	9225	
			Moss Back Mbr	20-60		
	Trmt	Moenkopi Fm	Upper member	550-700	9520	
	Trms		Sinbad Ls Mbr	50	10460	
	Trmbd		Black Dragon Mbr	250-350		
PERM	Ppc	Kaibab/Park City Fm		170	10890	
	Pwr	White Rim Sandstone		500-700	11135	

CO_2 Source

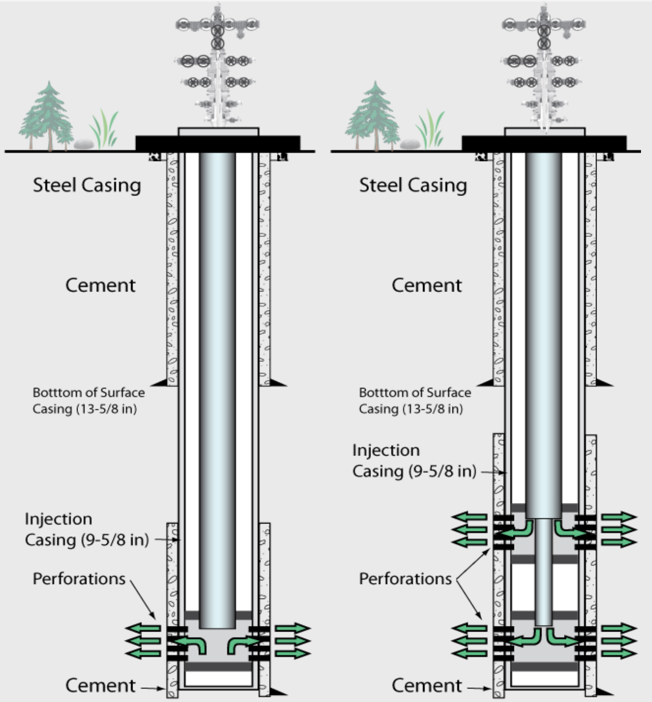
Methane Producer

CO_2 Sink

Seal

† Geologic symbols for correlation to units in Morgan (2007)

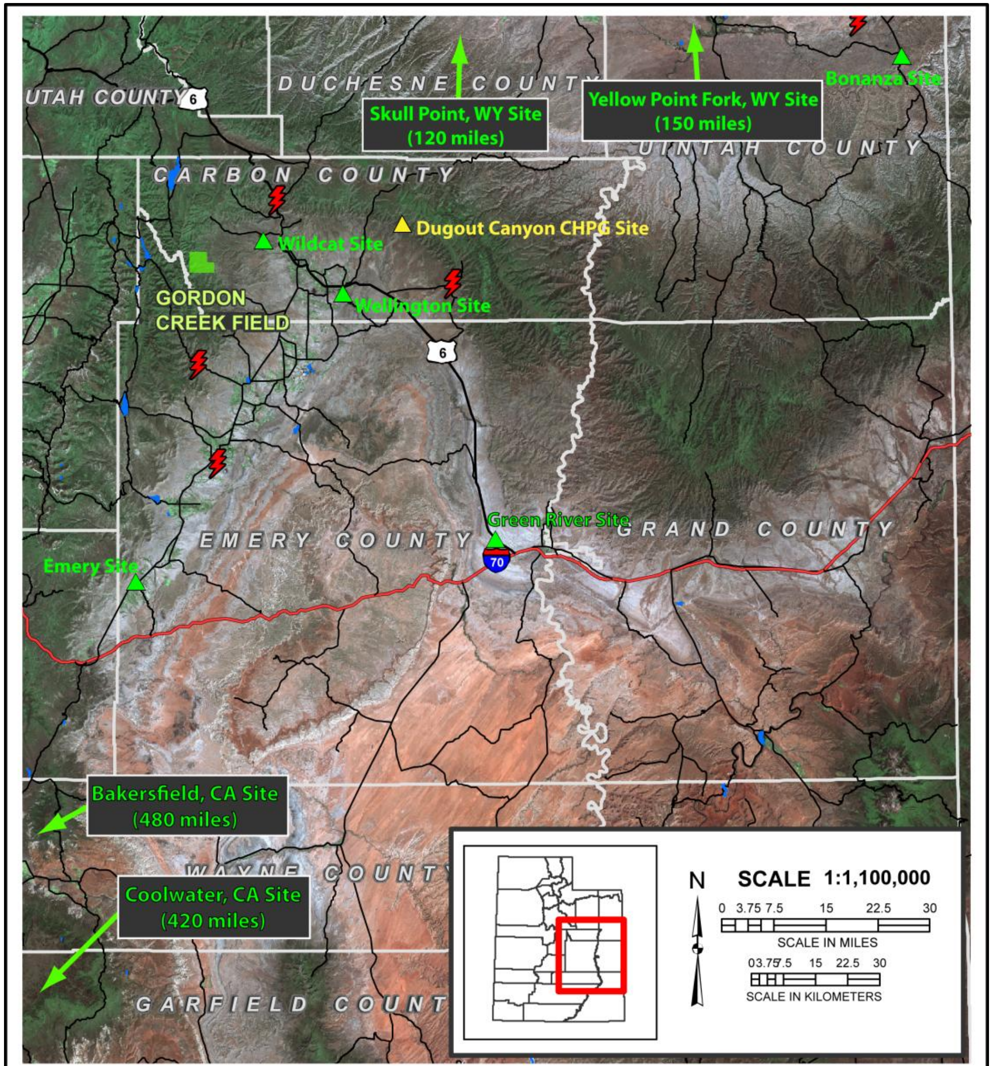
Modified from Hintze (1992)



Single zone Injection (Navajo Fm):

Dual zone Injection (Entrada & Navajo Fm)

Project Site Description: Gordon Creek, Utah



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			Tununk Sh Mbr	200-300	**4000**	
	Kd	Dakota Sandstone		0-30	**4025**	
	Kcm	Cedar Mtn Fm	Upper member	150-750	**4120**	
			Buckhorn Cg Mbr	0-50		
JURASSIC	Jm	Morrison Formation		800±	**4460**	
	Js	Summerville Formation		120-180	**5895**	
	Jct	Curtis Formation		140-180	**6275**	
	Je	Entrada Formation		150-950	**6585**	
	Jc	Carmel Formation		300-700	**7650**	
	Jc	Page Sandstone		<70		
	Jgc	Navajo Sandstone		150-300	**8400**	
		Kayenta Formation		120-200	**8750**	
		Wingate Sandstone		300-400	**8885**	
TRIASSIC	Trc	Chinle Fm	Upper member	200-300	**9225**	
			Moss Back Mbr	20-60		
	Trmt	Moenkopi Fm	Upper member	550-700	**9520**	
	Trms		Sinbad Ls Mbr	50	**10460**	
	Trmbd		Black Dragon Mbr	250-350		
PERM	Ppc	Kaibab/Park City Fm		170	**10890**	
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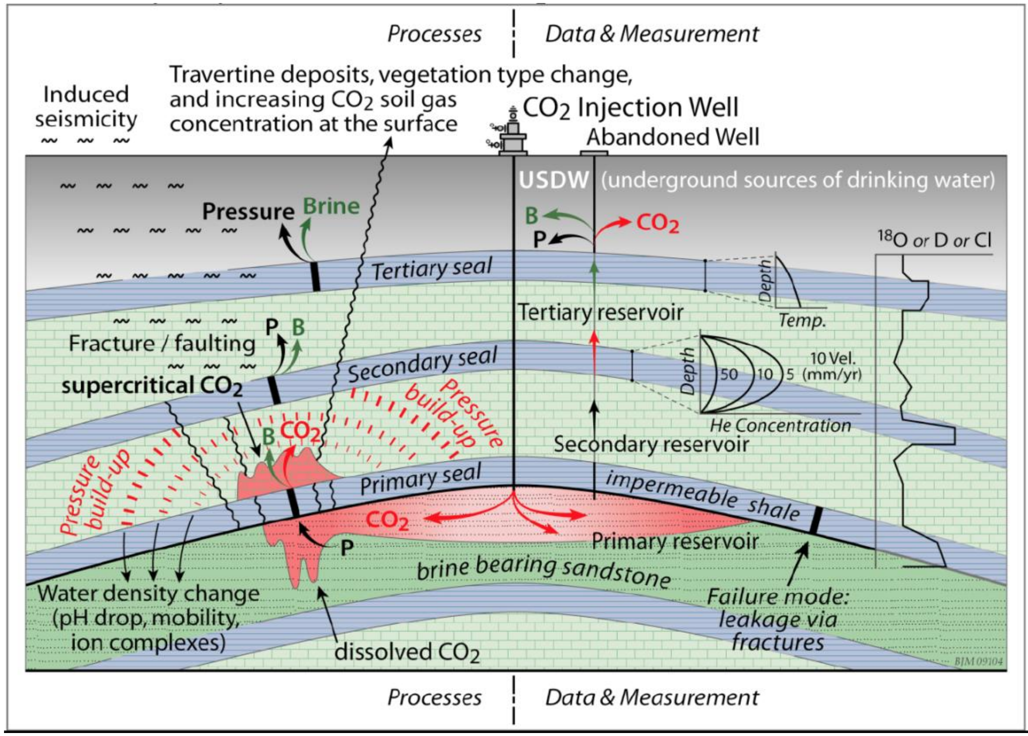

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